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Gilbert et al.

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(54) **SELF-INSTALLING ANCHOR**

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Related U.S. Application Data

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(51) **Int. Cl.**
B63B 21/32 (2006.01)
B63B 21/34 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B63B 21/26*** (2013.01); ***B63B 21/38*** (2013.01); *B63B 21/50* (2013.01)

(58) **Field of Classification Search**
CPC B63B 2021/26; B63B 21/29; B63B 21/30; B63B 31/32; B63B 31/36; B63B 21/38;
(Continued)

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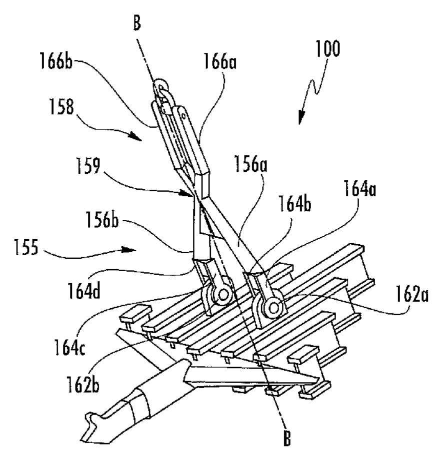
(74) *Attorney, Agent, or Firm* — Meunier Carlin & Curfman LLC

(57) **ABSTRACT**

The self-installing anchor is configured for falling vertically through the water, embedding vertically into the soil, rotating and translating diagonally deeper through the soil in response to the anchor line load being transmitted to it, and achieving its maximum holding capacity with the anchor line acting normal to the fluke. In various implementations, a coupling mechanism at one end of the shank is engaged with a bearing surface at an entry end of the fluke to hold the shank close to the fluke while falling through the water and embedding vertically into the soil. The coupling mechanism provides eccentricity to the load applied and allows for the rotation of the anchor. The coupling mechanism is disengaged at a predetermined angle, liberating one end of the shank, and the point of application of the force on the anchor is modified to make it dive deeper into the soil.

14 Claims, 20 Drawing Sheets



(51) **Int. Cl.**

B63B 21/26	(2006.01)
B63B 21/38	(2006.01)
B63B 21/50	(2006.01)

(58) **Field of Classification Search**
CPC ... B63B 21/40; B63B 21/42; B63B 2021/262; B63B 2021/265
USPC 114/295, 297, 299, 301, 304, 309, 310
See application file for complete search history.

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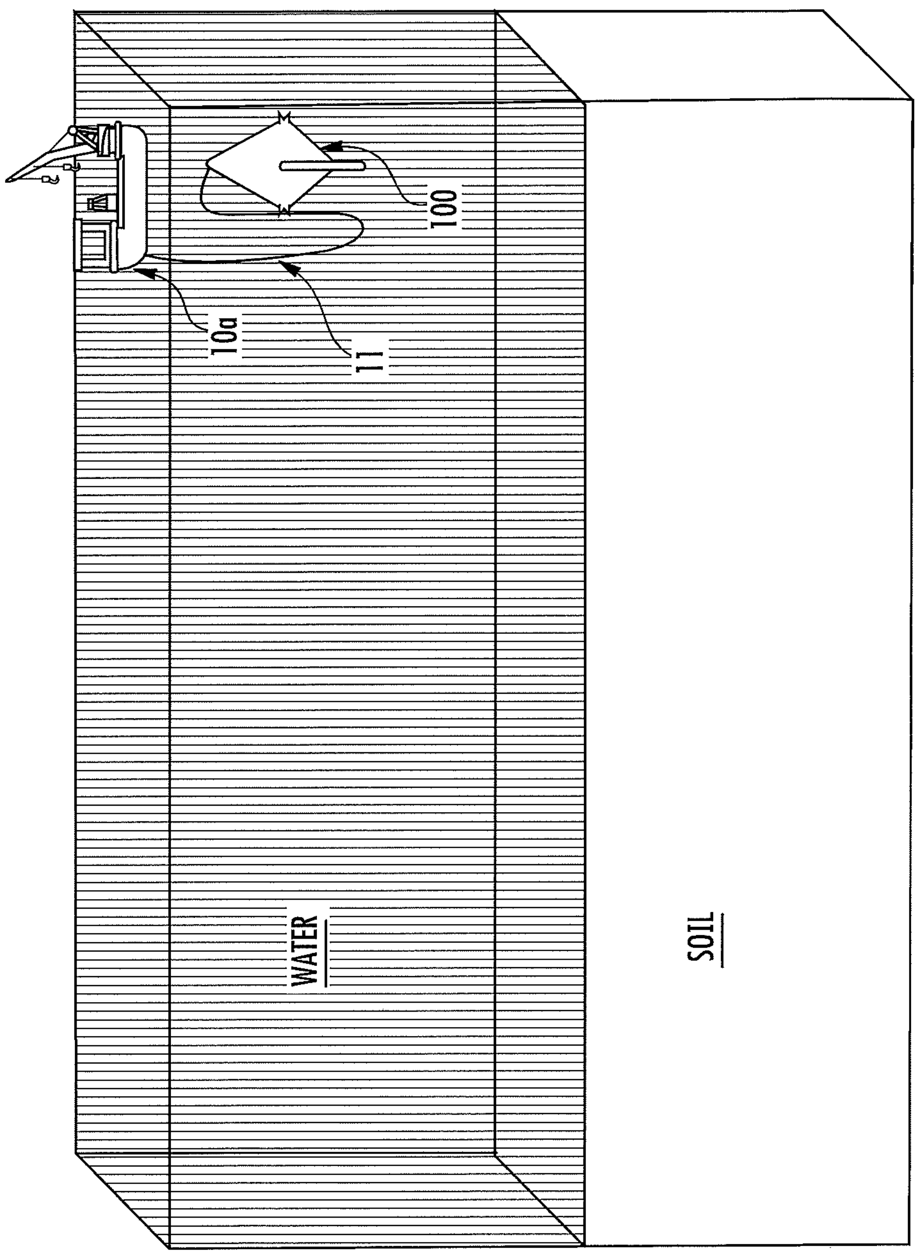


FIG. 1

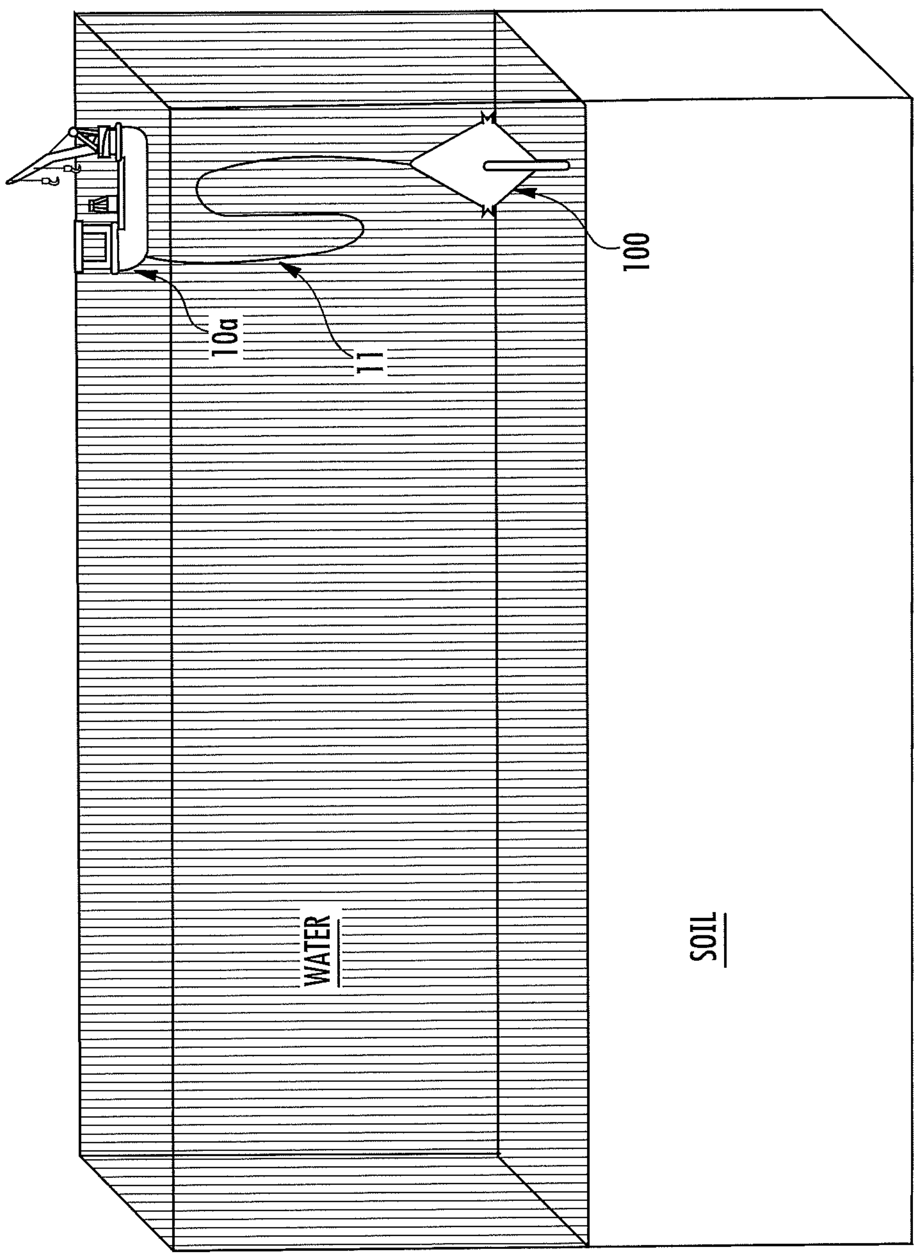


FIG. 2

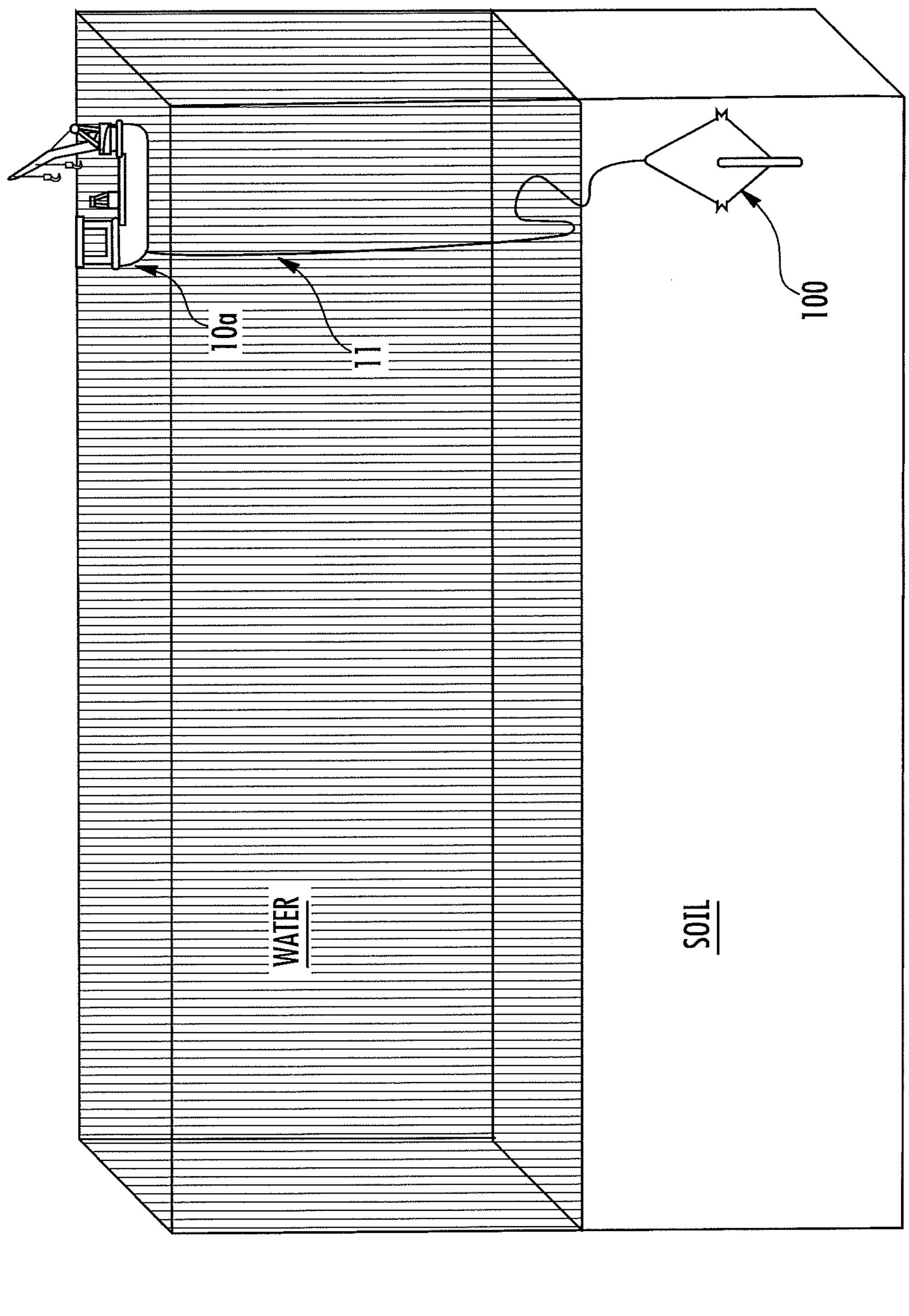


FIG. 3

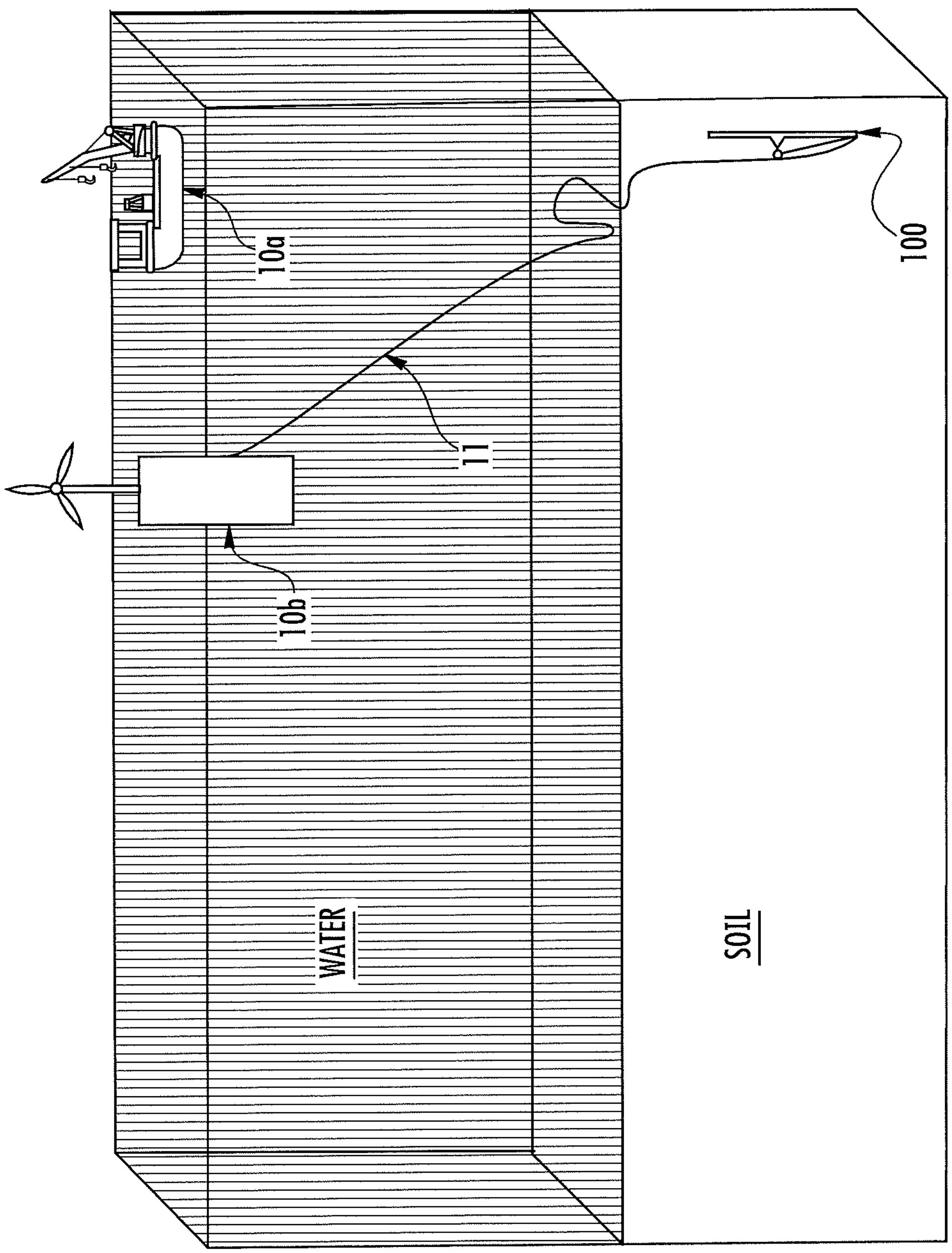
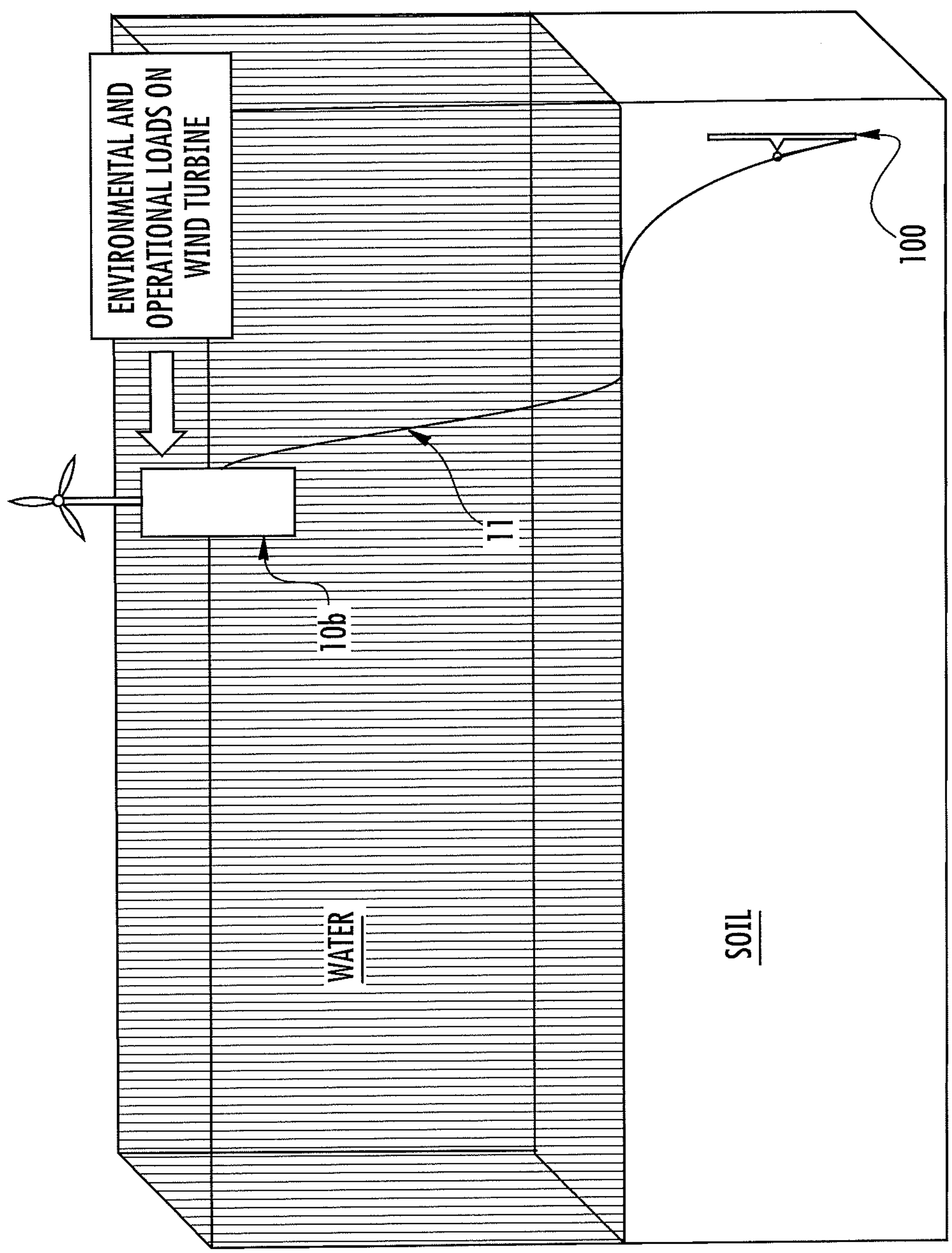


FIG. 4


ENVIRONMENTAL AND
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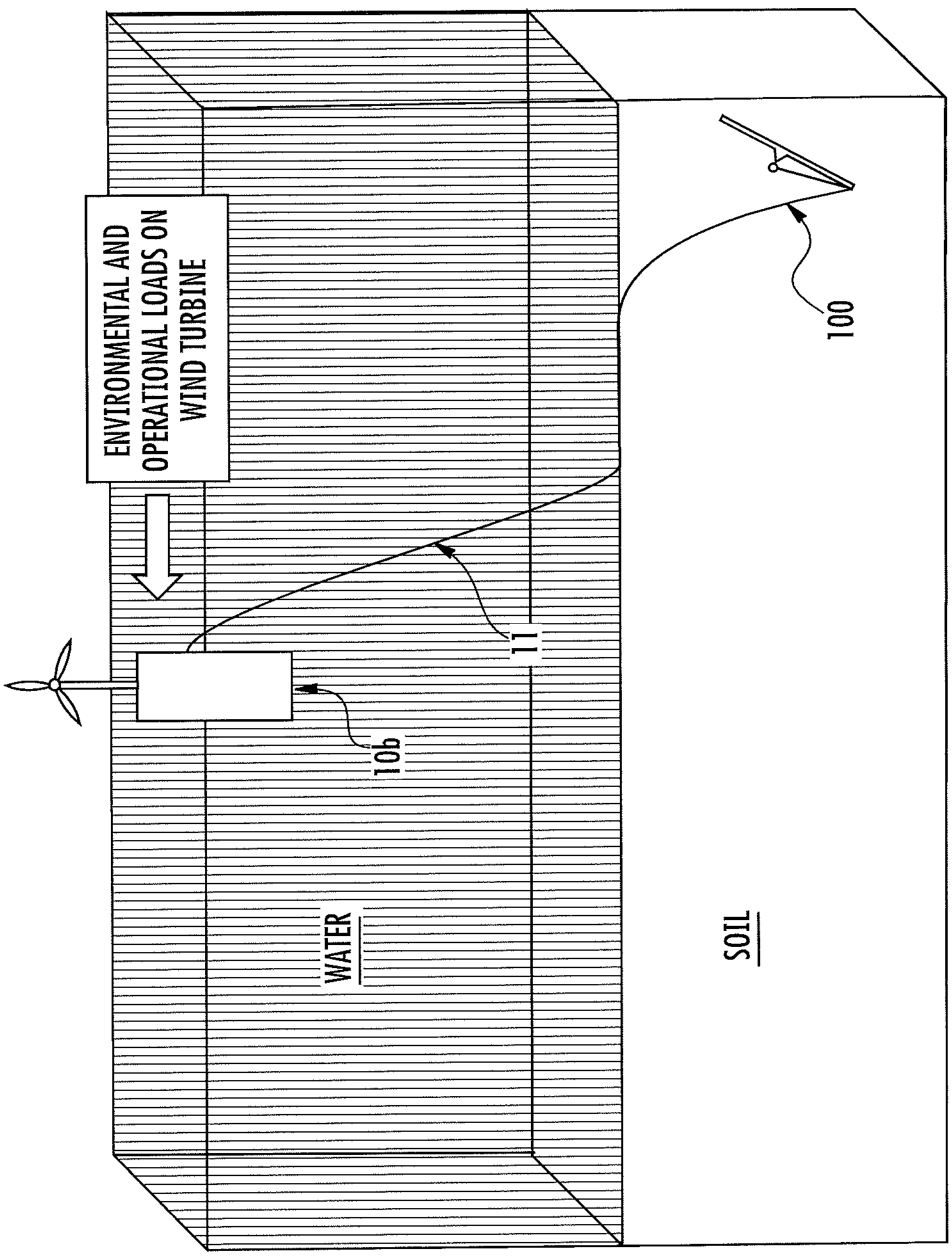
WIND TURBINE
10b
11
100
WATER
SOIL

FIG. 5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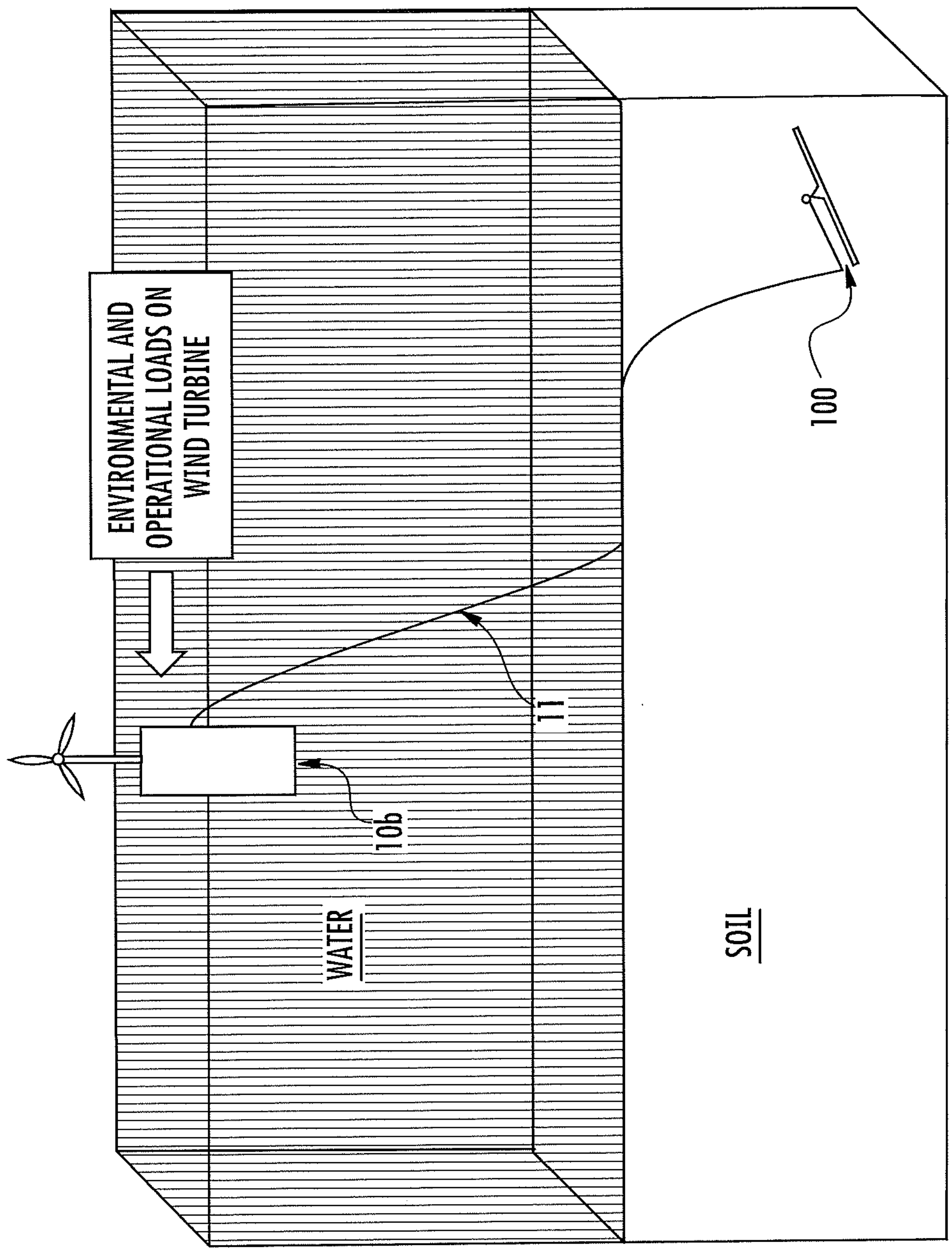
11
10b
WATER
SOIL

FIG. 6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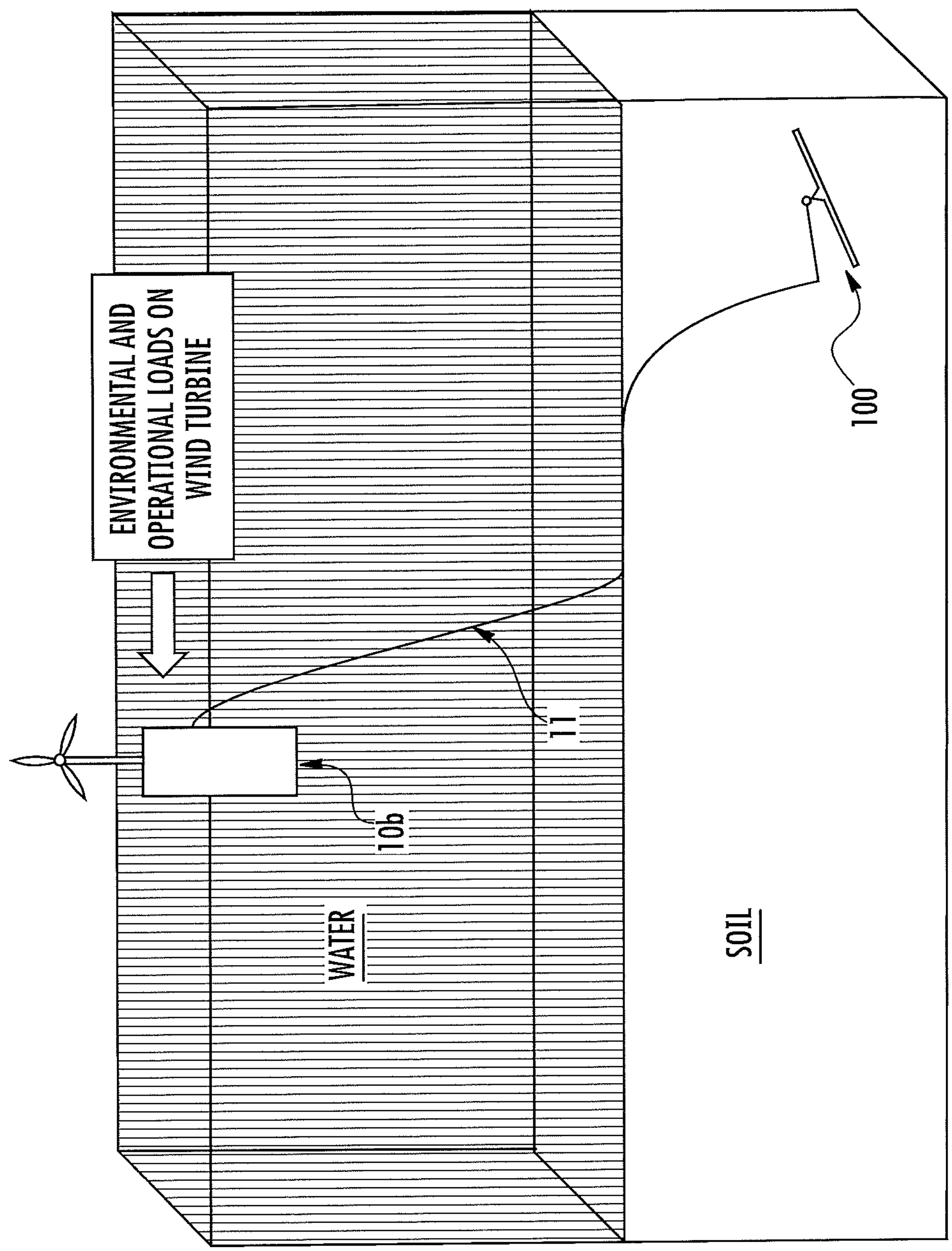
11
100
WATER
SOIL

FIG. 7


ENVIRONMENTAL AND
OPERATIONAL LOADS ON
WIND TURBINE
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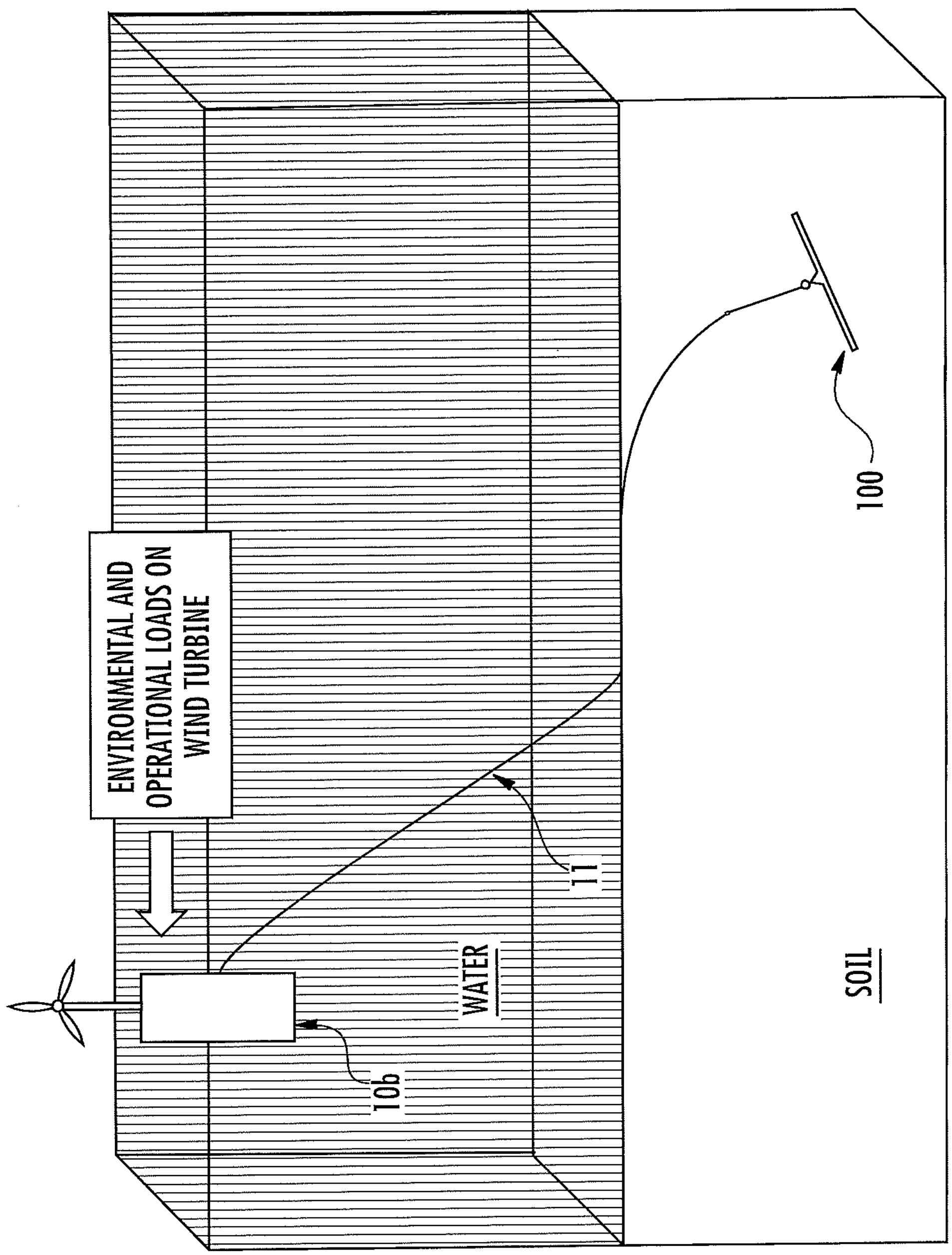
SOIL
10b
11
100

FIG. 8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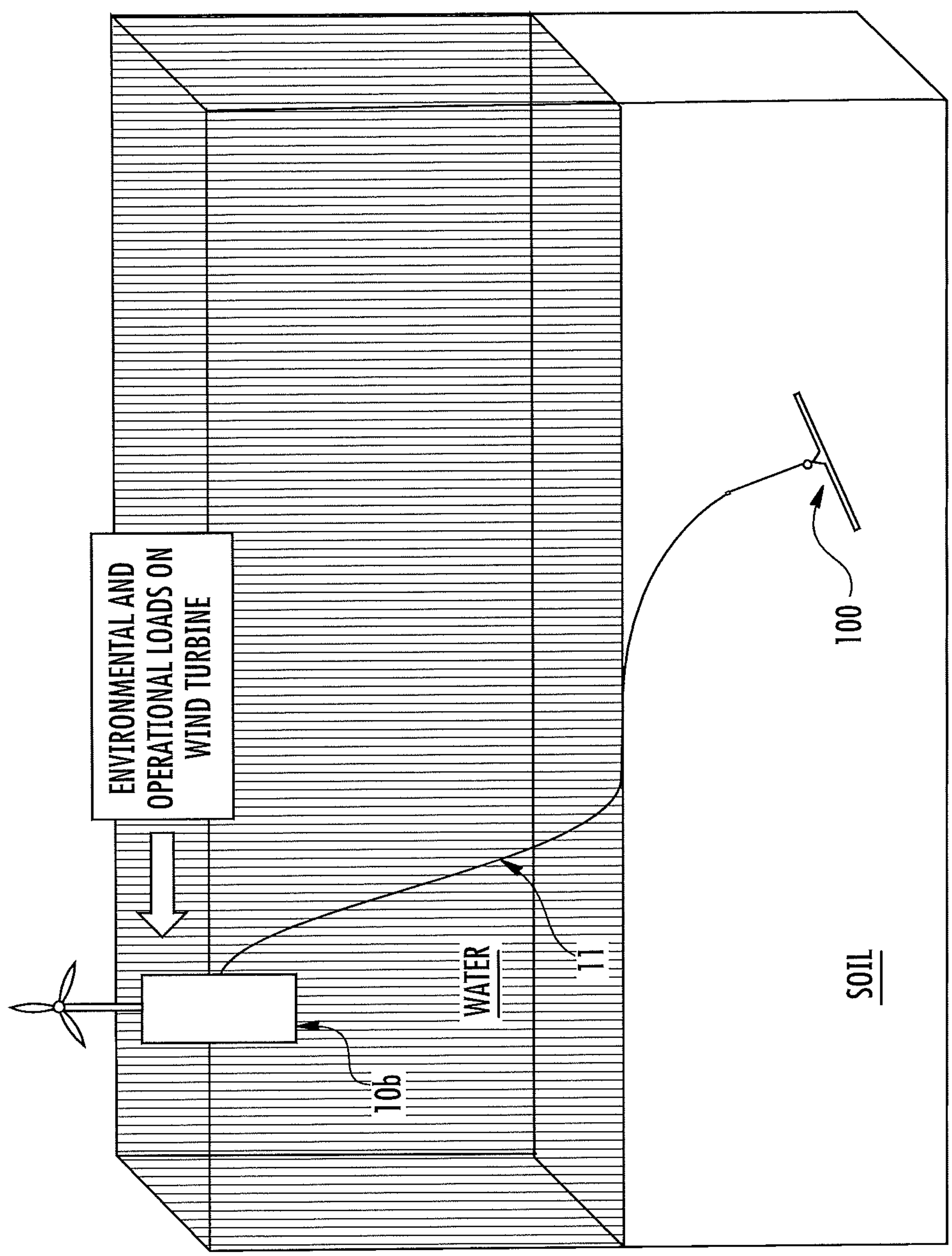
WATER
SOIL
10b
11
100

FIG. 9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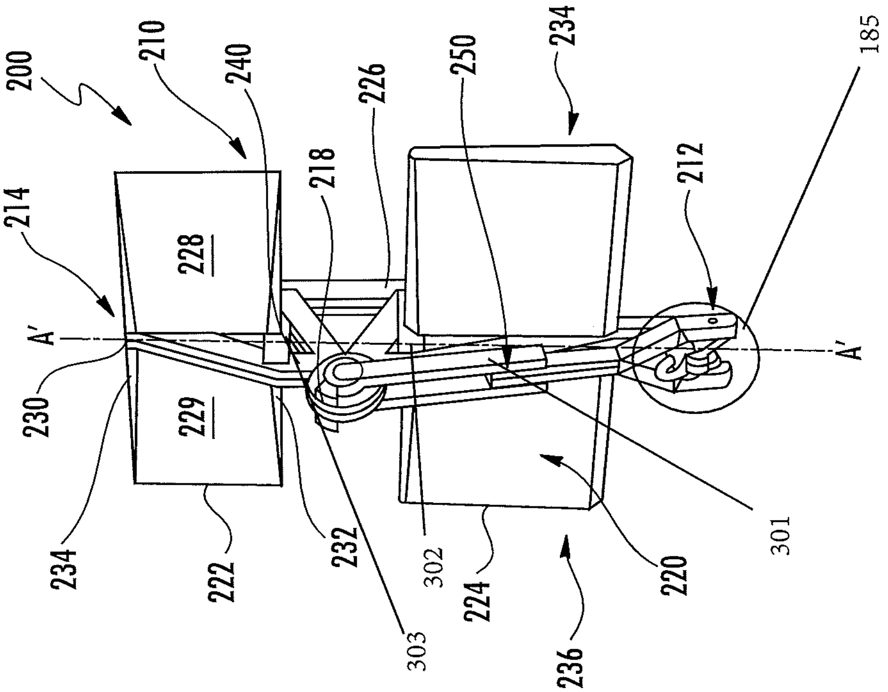
WIND TURBINE
WATER
SOIL
10b
11
100

FIG. 10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210
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226
250
234
185
214
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212
A'
A'
230
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234
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232
303
302
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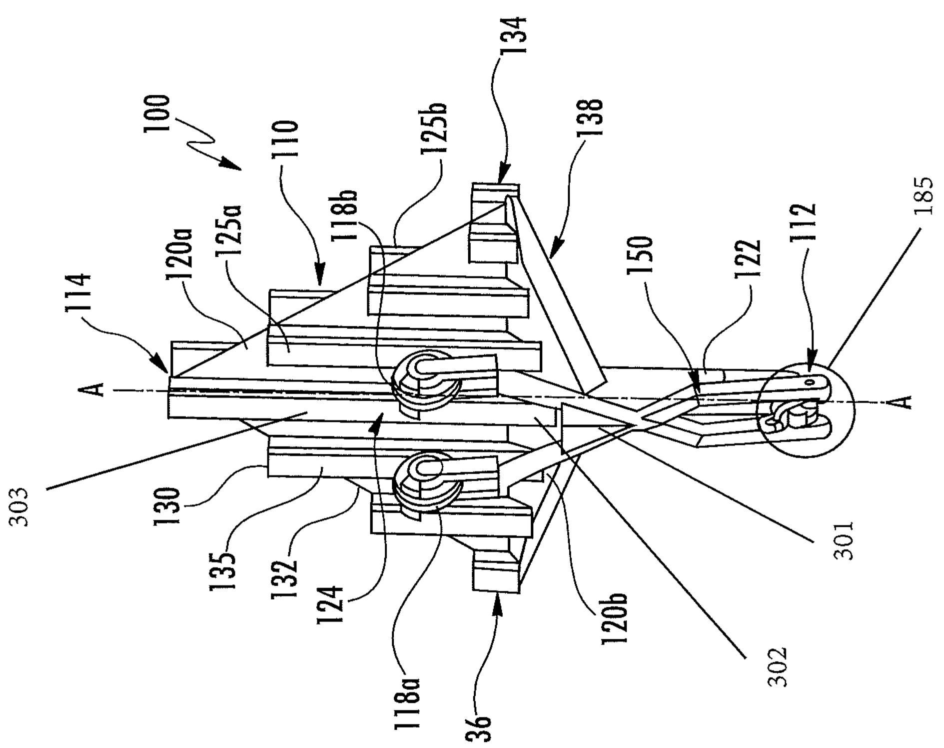
236
220
301

FIG. 14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110
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120a
125a
125b
118b
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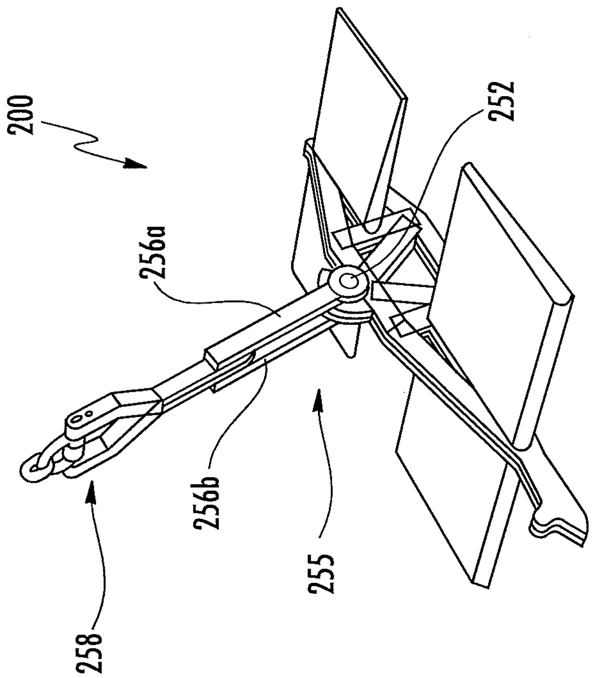
118a
136
120b
302
301

FIG. 11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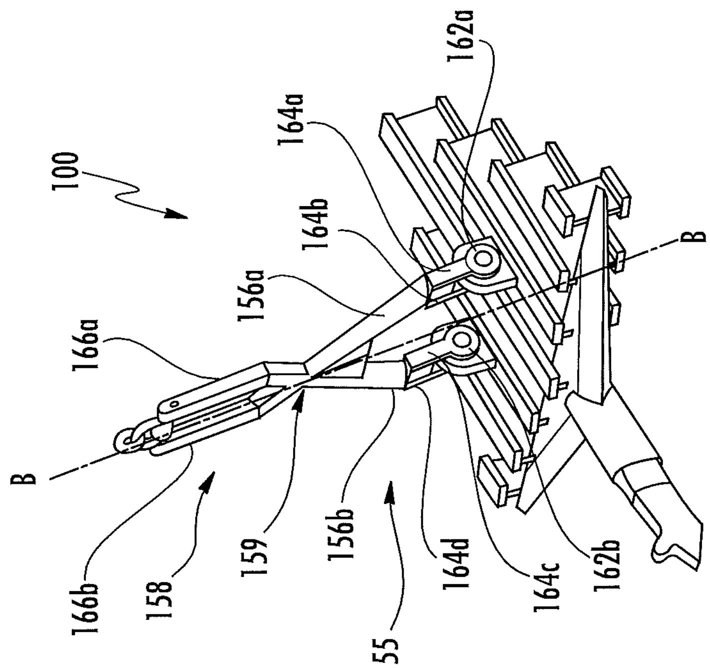
256a
256b
255
258

FIG. 15


100
162a
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164b
156a
166a
B
B
166b
158
159
156b
155
164d
164c
162b

FIG. 12

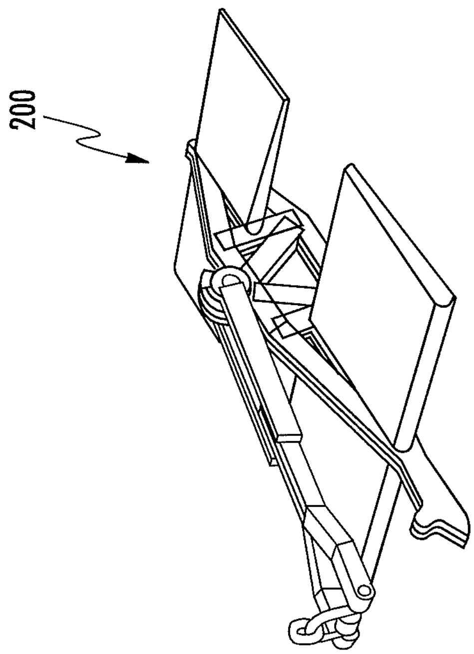

FIG. 16

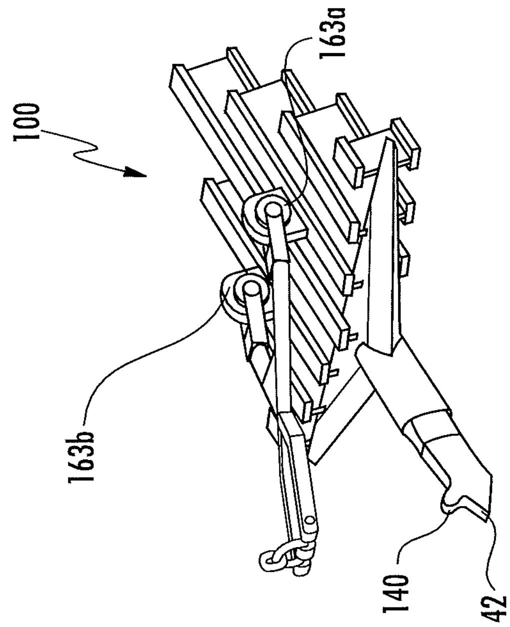

FIG. 13

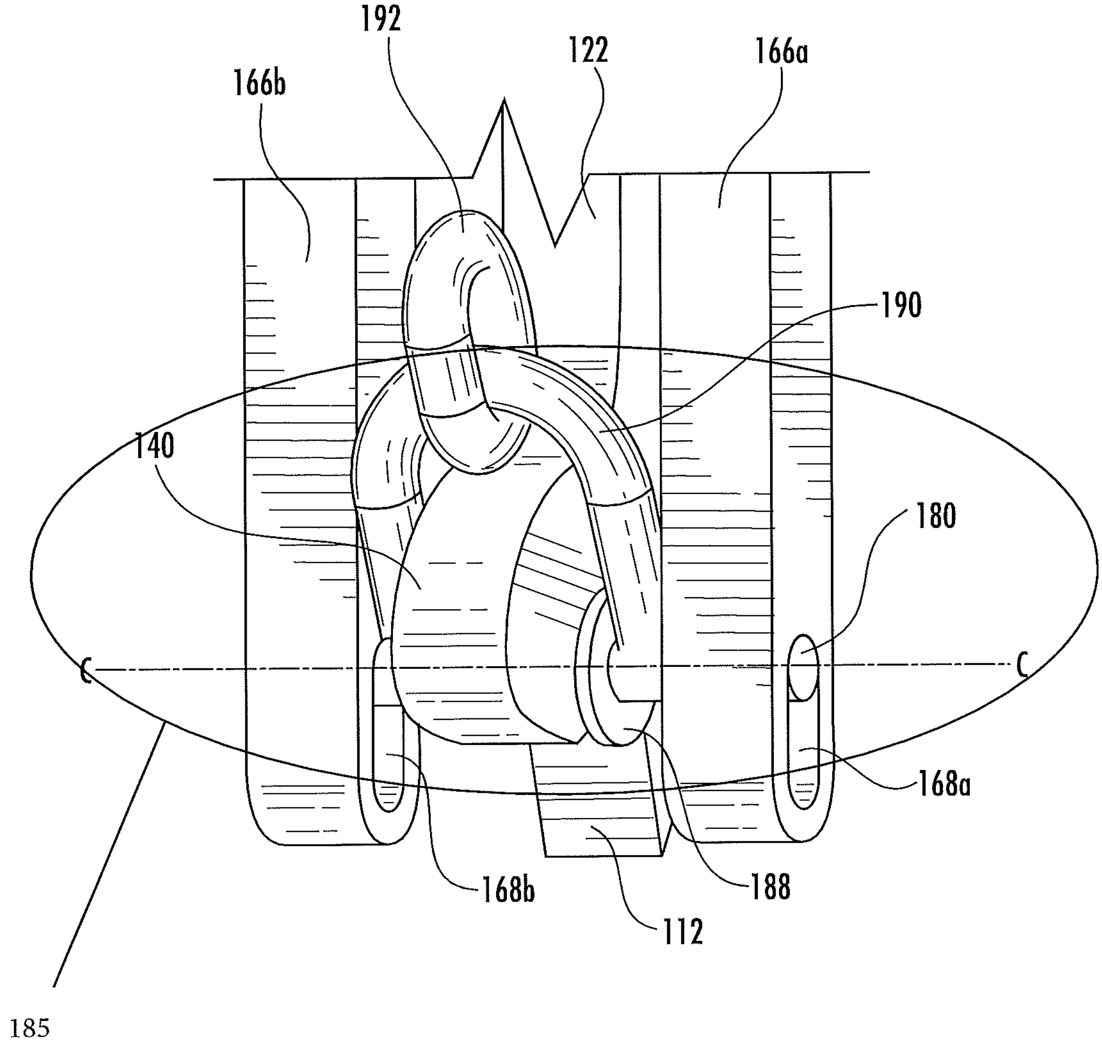

FIG. 17

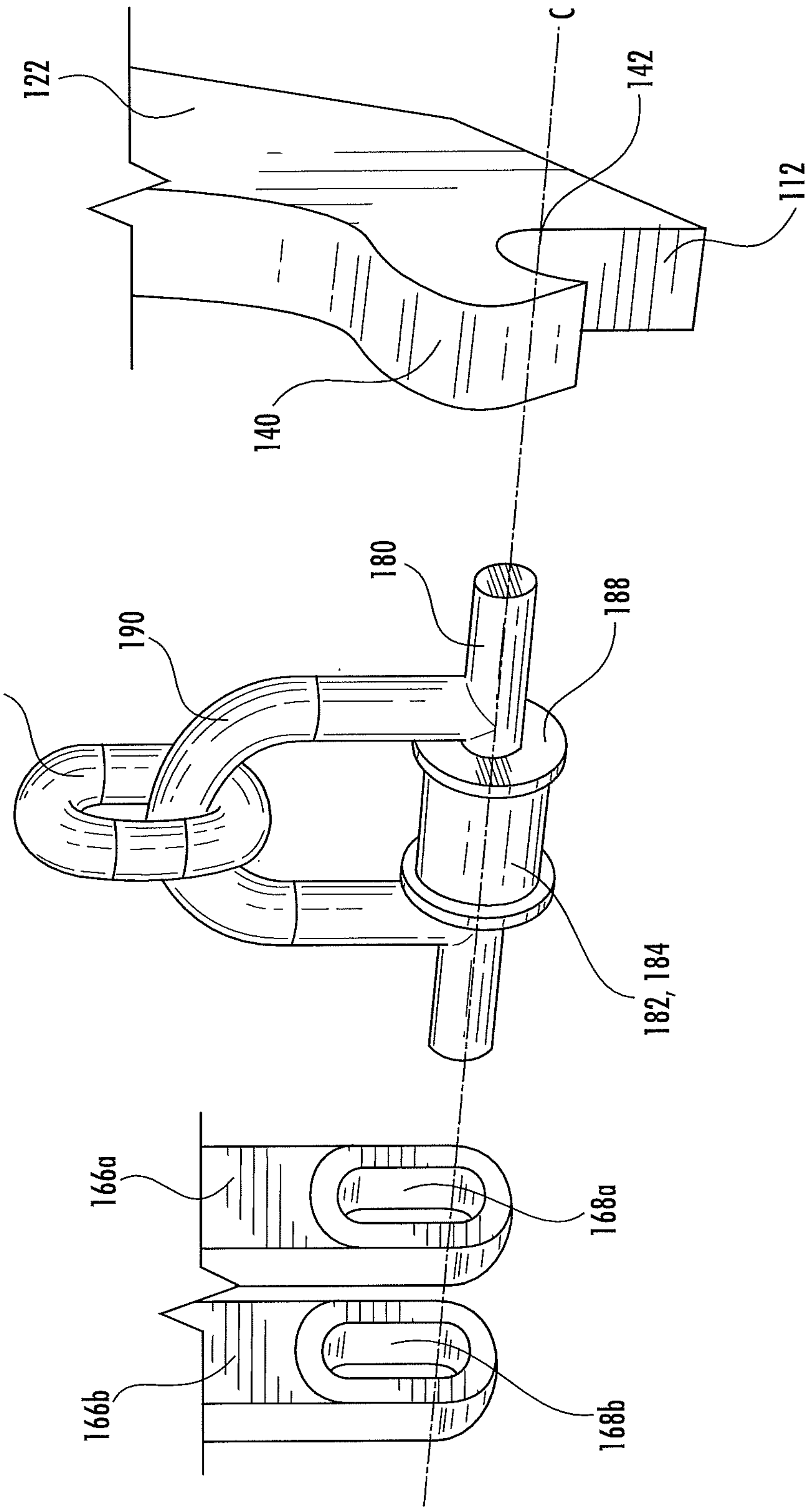

FIG. 18

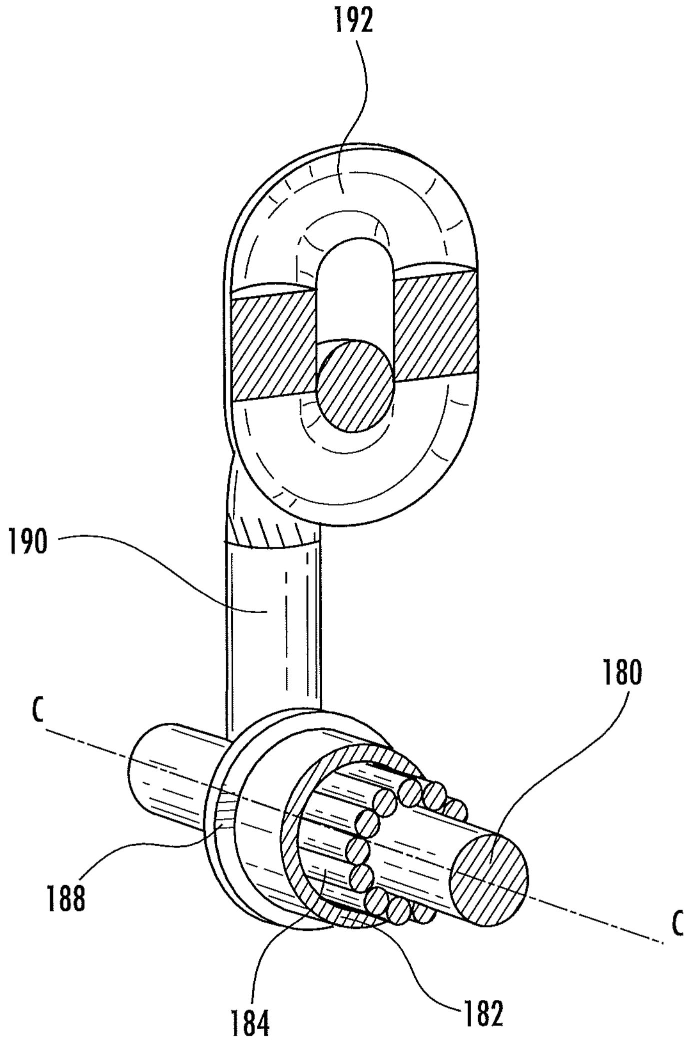

FIG. 19

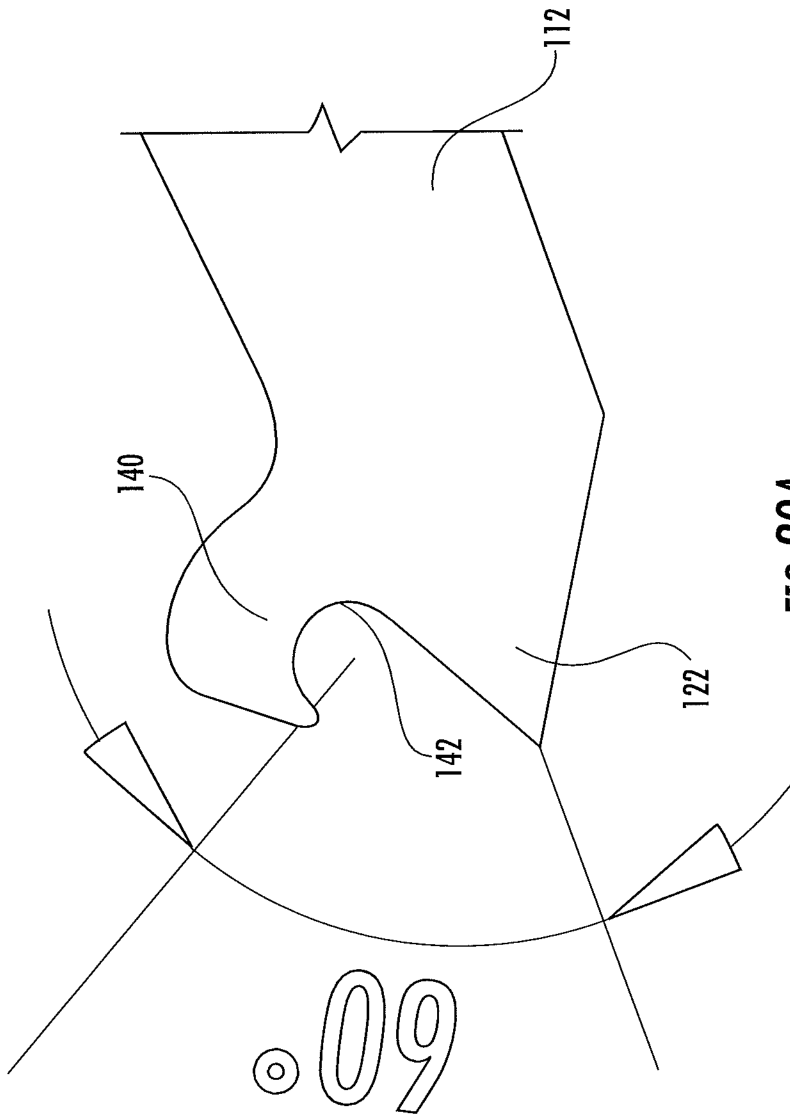

FIG. 20A

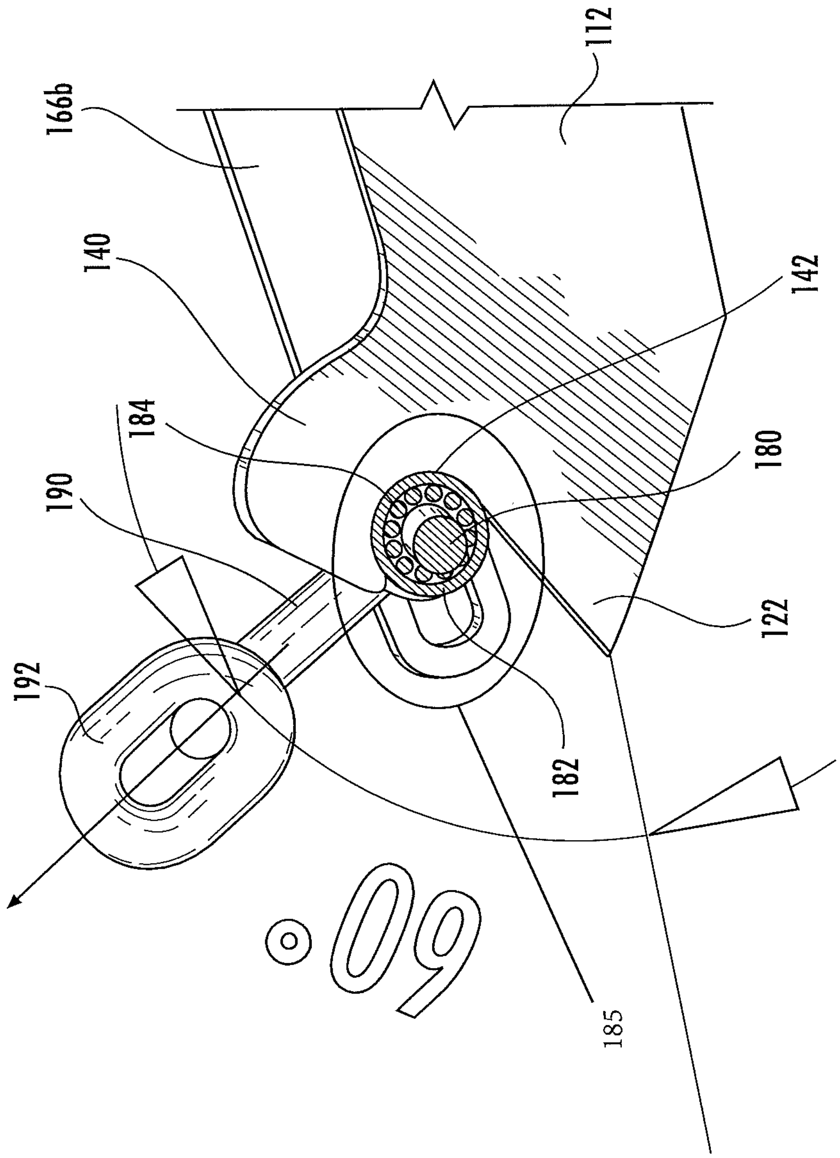

FIG. 20B

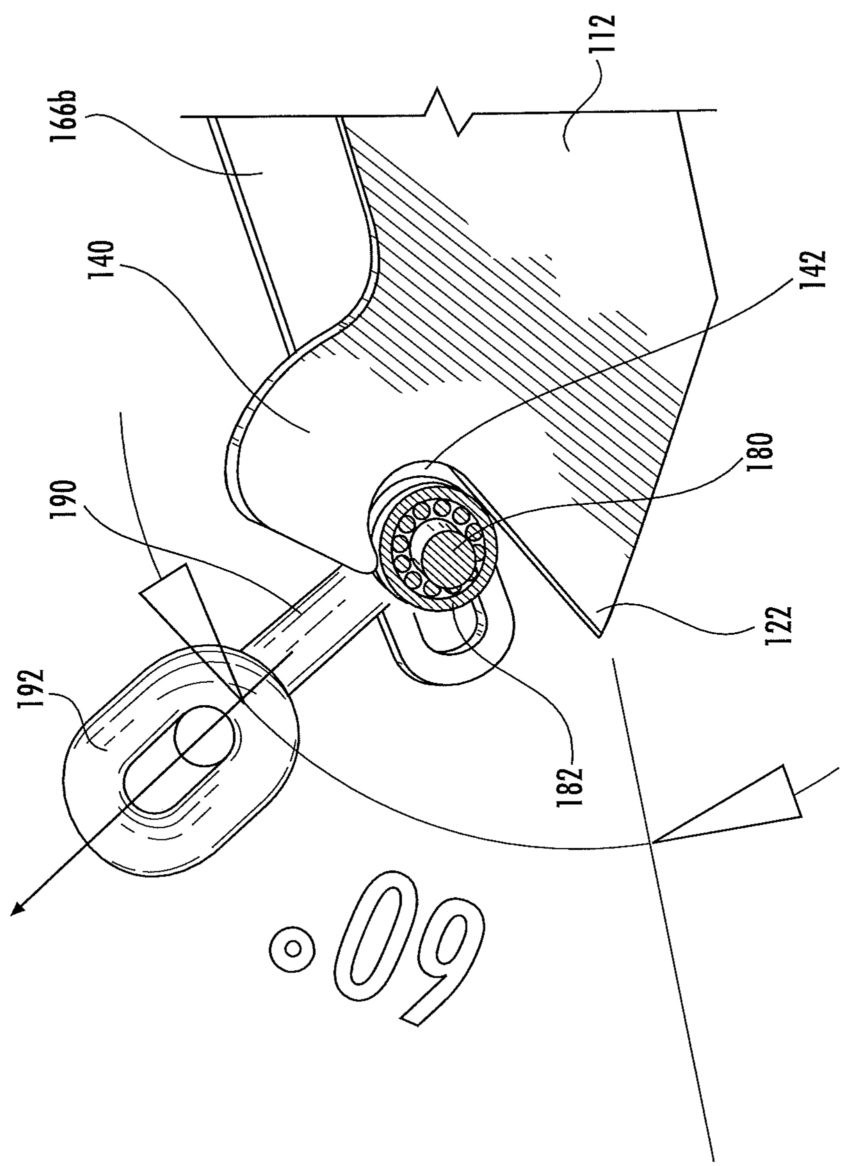

FIG. 20C

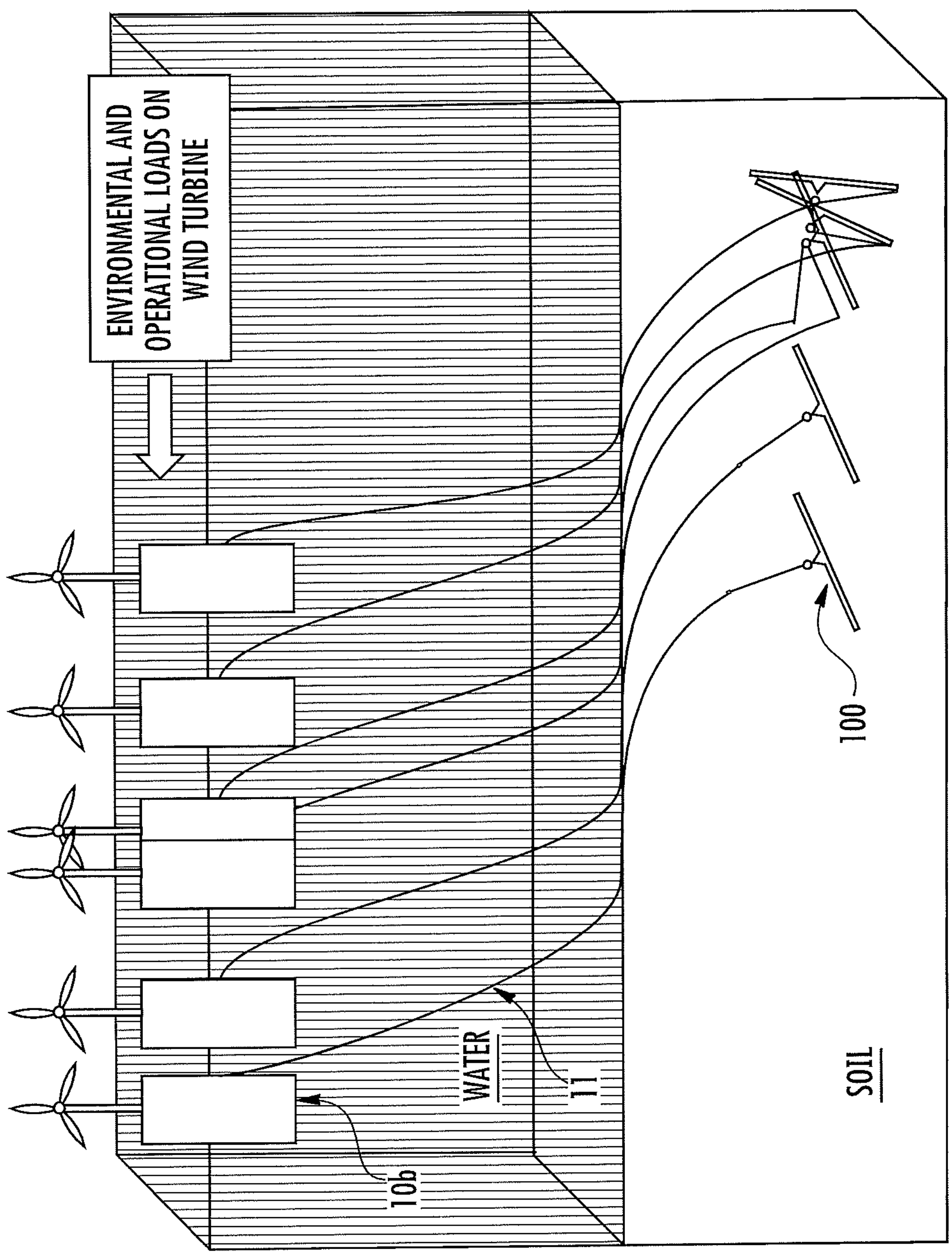
ENVIRONMENTAL AND OPERATIONAL LOADS ON WIND TURBINE
WATER
SOIL
11
10b
100

FIG. 21

SELF-INSTALLING ANCHOR

CROSS REFERENCE FOR RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 62/128,577 entitled "Self-Installing Anchor," filed Mar. 5, 2015, and U.S. Provisional Patent Application No. 62/146,726 entitled "Self-Installing Anchor," filed Apr. 13, 2015, the contents of which are herein incorporated by reference in their entireties.

GOVERNMENT LICENSE RIGHTS

This invention was made with government support under NSF #CMMI-1301211 project awarded by U.S. National Science Foundation. The government has certain rights in the invention.

BACKGROUND

Offshore facilities generate nearly a third of the energy used in the U.S., and they have the potential to provide significantly more energy both with oil and gas and with renewable sources including wind, wave, current and thermal energy. The challenge in the future will be to produce this energy at a minimal cost and with minimal impact to the environment. Conventional anchors for offshore facilities are not very efficient, essentially requiring that a load near their desired capacity be applied during installation at considerable expense and environmental impact, when in service, it is unlikely that the anchor will ever experience a load that large. Additionally, the installation of conventional anchors generally requires multiple construction, support, and surveying vessels to be accomplished.

Accordingly, an improved anchor is needed that overcomes the disadvantages of conventional anchors.

BRIEF SUMMARY

Various implementations of a self-installing anchor are configured for falling vertically through the water, embedding vertically into the soil, rotating and translating diagonally deeper through the soil in response to the anchor line load being transmitted to it, and achieving its maximum holding capacity with the anchor line acting normal to the fluke. In various implementations, a coupling mechanism at one end of the shank is engaged with a bearing surface at an entry end of the fluke to hold the shank close to the fluke while falling through the water and embedding vertically into the soil. The coupling mechanism provides eccentricity to the load applied and allows for the rotation of the anchor. The coupling mechanism is disengaged at a predetermined angle, liberating one end of the shank, and the point of application of the force on the anchor is modified to make it dive deeper into the soil.

In particular, various implementations of the anchor include a shank, a fluke, a bearing surface, and a coupling mechanism. The shank has first and second ends. The fluke has an entry end, a trailing end, and a central portion intermediate the entry and trailing ends. The bearing surface is disposed adjacent the entry end of the fluke. The coupling mechanism is disposed adjacent the second end of the shank. The coupling mechanism is configured for: (1) engaging the bearing surface of the fluke during passage of the anchor through water and while embedding vertically into the soil, (2) transmitting the force applied by the anchor line to the

front of the fluke causing the anchor to pitch, and (3) disengaging the bearing surface when a threshold angle between the force applied by the anchor line and the fluke is attained causing the anchor to translate near parallel to the fluke. A first end of the shank is rotatably coupled adjacent the central area of the fluke. When the coupling mechanism is engaged with the bearing surface, a center of mass of the anchor is below a center of drag and a center of lift of the anchor to keep the anchor vertically oriented such that the entry end of the fluke is vertically below and aligned with the trailing end of the fluke while passing through water. And, a weight of the anchor urges the anchor through the water and into soil below the water. The center of mass refers to the point on the anchor through which the force of gravity acts and is obtained by finding the location about which the sum of the moments due to the masses of the individual components of the anchor is equal to zero. The center of mass can be calculated based on the geometry of the anchor or measured with a scale. The center of lift refers to the point on the anchor through which the force of lift acts as the anchor is moving through a fluid. The center of lift is obtained by finding the location about which the sum of the moments due to the lift forces on individual components of the anchor is equal to zero. The center of lift can be calculated approximately by dividing the anchor up into sets of rectangular plates or measured in a flow test. The center of drag refers to the point on the anchor through which the force of drag acts as the anchor is moving through a fluid. The center of drag is obtained by finding the location about which the sum of the moments due to the drag forces on individual components of the anchor is equal to zero. The center of drag can be calculated approximately by dividing the anchor up into sets of rectangular plates or measured in a flow test.

In some implementations, at least a portion of the fluke is diamond shaped. For example, the diamond shaped portion of the fluke may be adjacent the trailing end. The fluke may also include a planar base and T-shaped protrusions that extend from a front face and a rear face of the base as viewed from the trailing end of the fluke. In certain implementations, the trailing end of the fluke is triangular-shaped.

In other implementations, the fluke may include first and second wings. The first wing is adjacent the trailing end of the fluke, and the second wing is disposed between the trailing end and the entry end of the fluke. The second wing may have a rectangular cross sectional shape as viewed from a front or a rear surface of the fluke and an airfoil cross-sectional shape as viewed from a side surface of the fluke. The first wing may also have a rectangular cross-sectional shape as viewed from the front or rear surface of the fluke. Further, in some implementations, the first wing may have a hexagonally shaped cross-section as viewed from the side of the fluke.

In some implementations, a protrusion extends outwardly from the front face of the fluke. A proximal end of the protrusion is disposed adjacent the front face of the entry end of the fluke, and the bearing surface comprises a surface of the protrusion that faces the entry end of the fluke. The coupling mechanism includes two arms spaced apart from each other disposed at the second end of the shank and a pin. Each of the two arms defines an elongated slot there through, and the elongated slots are aligned with each other along a first axis that extends perpendicularly through the arms and a second axis that extends through each end of the shank. The slots have the same slot width and length. The pin is disposed between the two arms and extends through the elongated slots. The pin is configured to move through the slots along the second axis. A central portion of the pin engages the bearing surface to hold the second axis adjacent a third axis that extends through each end of the fluke when the pin is disposed at proximal ends of the elongated slots, and the central portion of the pin disengages the bearing surface when the pin is disposed at distal ends of the elongated slots, allowing the second axis of the shank to rotate about the second end of the shank relative to the third axis of the fluke.

In certain implementations, the central portion of the pin includes a spool that extends radially outwardly from an axis of the pin that extends through the ends of the pin. The spool is configured for rotating freely around the axis of the pin. In addition, ends of a U-shaped hook may be coupled to the pin adjacent each end of the spool. A link may be coupled to the U-shaped hook, and the link is for coupling to the anchor line.

In other implementations, the ends of the U-shaped hook may be coupled to the pin adjacent a central portion of the pin. A link may be coupled to the U-shaped hook that is configured for coupling with a line that extends between the anchor and the vessel.

Furthermore, in certain implementations, the first end of the shank comprises first and second arms that are spaced apart from each other and are each rotatably coupled to the central portion of the fluke.

BRIEF DESCRIPTION OF THE DRAWINGS

The components in the drawings are not necessarily to scale relative to each other and like reference numerals designate corresponding parts throughout the several views:

FIG. **1** is a front view of an anchor after being dropped into a body of water from an installation vessel on the surface of the water to which the anchor is coupled via an anchor line.

FIG. **2** is a front view of the anchor in FIG. **1** when the anchor reaches soil below the water.

FIG. **3** is a front view of the anchor in FIG. **1** after it has penetrated the soil.

FIG. **4** is a side view of the anchor in FIG. **1** after the installation vessel transfers the anchor line to the facility that is going to be anchored.

FIG. **5** is a side view of the anchor in FIG. **1** showing how the environmental and operational loads act on the moored vessel.

FIG. **6** is a side view of the anchor in FIG. **1** showing how, when the force applied by the anchor line reaches a certain threshold, the anchor begins to pitch within the soil.

FIG. **7** is a side view of the anchor in FIG. **1** showing the coupling mechanism disengaged and the shank liberated, starting to rotate without the fluke moving.

FIG. **8** is a side view of the anchor in FIG. **1** while the shank is rotating without the fluke moving.

FIG. **9** is a side view of the anchor in FIG. **1** when the shank has reached alignment with the force from the anchor line and the force is again being transmitted to the fluke, making it dive deeper into the soil.

FIG. **10** is a side view of the anchor in FIG. **1** when the shank is in a fully extended position such that the anchor line extends normal to the fluke, and the maximum capacity of the anchor is attained.

FIG. **11** is a perspective front view of an anchor in the installation configuration according to one implementation.

FIG. **12** is a perspective front view of the anchor of FIG. **11** in the final holding arrangement.

FIG. **13** is a perspective front view of the anchor of FIG. **11** between the installation and final holding arrangements.

FIG. **14** is a perspective front view of an anchor in an installation arrangement according to another implementation.

FIG. **15** is a perspective front view of the anchor in FIG. **14** in the final holding arrangement.

FIG. **16** is a perspective front view of the anchor of FIG. **14** between the installation and holding arrangements.

FIG. **17** is a close up perspective front view of the entry end of the anchor, the proximal end of the shank, the coupling mechanism, the protrusion, and a bearing surface in the installation configuration of the implementations shown in FIGS. **11** through **16**.

FIG. **18** is an exploded view of the entry end of the anchor, the proximal end of the shank, the coupling mechanism, the protrusion, and the bearing surface of the implementation shown in FIG. **17**.

FIG. **19** is a partial cut out view of the coupling mechanism shown in FIG. **18**.

FIG. **20**A is a lateral view of the bearing surface shown in FIG. **18**, presenting, as an example, a threshold angle at which the coupling mechanism would be disengaged.

FIG. **20**B is a partial cut view of the entry end of the anchor, the proximal end of the shank, the coupling mechanism, the protrusion, and the bearing surface of the implementation shown in FIG. **17**, when the force applied by the anchor line through the disengaging mechanism has reached the threshold angle.

FIG. **20**C is a partial cut view of the entry end of the anchor, the proximal end of the shank, the coupling mechanism, the protrusion, and the bearing surface shown in FIG. **17**, when the force applied by the anchor line through the coupling mechanism has exceeded the threshold angle and the coupling mechanism is disengaging from the bearing surface.

FIG. **21** is a side view of the various positions shown in FIGS. **5-10** of the anchor during installation.

DETAILED DESCRIPTION

According to various implementations, an anchor includes a low-profile, high-bearing-area fluke and a shank. A first end of the shank is rotatably coupled to a central portion of the fluke, and a second end of the shank includes a coupling mechanism for engaging and disengaging with a bearing surface that extends outwardly from an entry end of the fluke. To install the anchor, the coupling mechanism is engaged against the bearing surface, which holds the shank close to the fluke, and an anchor line is coupled between the coupling mechanism and the vessel. The anchor is dropped through the water from a vessel, such that the entry end of the fluke is below a trailing end of the fluke. The center of mass of the anchor, where the force of gravity is applied, is below the center of drag and the center of lift, which allows the anchor to maintain a vertical orientation as it passes through the water, and recover the verticality in case of any perturbation. During the free fall through the water column, the anchor gets minimal or no resistance from the anchor line, which is reeled out, to allow the anchor to gain speed. After the anchor embeds into the soil below the water due to the kinetic energy with which it has reached the soil, the anchor line is transferred from the installation vessel to the facility that is going to be anchored.

As the environmental and operational loads act on the moored vessel, the anchor line transfers the force first to the soil via friction and then to the anchor. When the force applied by the anchor line to the anchor reaches a certain threshold, the anchor begins to pitch within the soil. When the angle between the force and the anchor has reached a predetermined value, the coupling mechanism is disengaged and the shank is liberated from the entry end of the fluke and starts rotating without the fluke moving. When the shank has reached alignment with the force from the anchor line it no longer rotates and the force is again transmitted to the fluke, making it dive deeper into the soil. As the anchor is diving deeper into the soil, the anchor line is traversing more, which makes the shank rotate further away from the fluke and ultimately reach its final position where the force applied by the anchor line and the shank are almost perpendicular to the fluke and the maximum holding capacity of the anchor is attained.

The shape of the anchor, its weight, and its ability to maintain a vertical orientation while passing through the water allow the anchor to drop to the soil below the water and penetrate into the soil due to gravity and without any additional assistance. In various implementations, the anchor may provide an increased holding capacity compared to conventional anchors having the same weight, which reduces the cost, effort, time, energy, and environmental impact of installation. For example, the anchor may penetrate into the soil twice as far as conventional anchors having the same weight. In addition, conventional anchors may include several drawbacks that are overcome by various implementations of the anchor. In particular, conventional anchors may need to be pulled into place with a separate installation vessel; they may only work in one type of soil or they may require parts that have to be selected based on the type of soil expected; and the angle between the shank and the fluke may be fixed and/or may require adjustment for certain types of soils. In some conventional anchors in which the shank opens up relative to the fluke, the anchors require a mechanism such as a shear pin that breaks at a threshold load, and the shear pin is selected based on the type of soil expected.

FIGS. **1** through **10** illustrate various views of anchor **100** being installed. FIG. **1** illustrates the anchor **100** as it starts free falling through the water. It is coupled to installation vessel **10***a* by an anchor line **11**. The anchor **100** gets minimal or no resistance from the anchor line **11**, which may be reeled out, to allow the anchor **100** to gain speed.

FIG. **2** illustrates the anchor **100** when it reaches the soil below the water. The anchor **100** reaches the soil with considerable velocity due to the force of gravity, allowing it to embed vertically into the soil. FIG. **3** illustrates the anchor **100** after it has penetrated vertically through the soil due to the kinetic energy with which it has reached the bottom of the body of water. FIG. **4** illustrates the anchor line after it has been transferred from the installation vessel **10***a* to the floating facility **10***b* to be moored.

FIG. **5** illustrates environmental and operational loads acting on the moored vessel **10***b*, causing the anchor line **11** to transfer the force first to the soil via friction and then to the anchor **100**. FIG. **6** illustrates how, after the force applied to the anchor **100** by the anchor line **11** reaches a certain threshold magnitude, the anchor **100** begins to pitch within the soil. FIG. **7** illustrates the configuration at which the threshold angle between the force and the anchor **100** has been reached, the coupling mechanism is disengaged, and the shank is liberated and is starting to rotate without the fluke moving.

FIG. **8** illustrates the shank during its rotation when the fluke is not moving. FIG. **9** illustrates the shank after it has reached alignment with the force from the anchor line **11**. At this point, the force is again transmitted to the fluke, making the fluke dive deeper into the soil. In FIG. **10**, the shank is in a fully extended position such that the anchor line **11** extends normal to the fluke. In this position, the maximum capacity of the anchor is attained.

FIGS. **11-13** provide close up views of anchor **100**, according to one implementation. In particular, FIG. **11** illustrates the anchor **100** in a closed configuration in which both ends of the shank **150** are coupled to the fluke **110**. The fluke **110** includes an entry end **112**, a trailing end **114**, a triangular-shaped upper base **120***a* and a triangular-shaped lower base **120***b* (as viewed from the front of the anchor **100**), an arm **122** extending between the lower base **120***b* and the entry end **112**, and hinge bosses **118***a*, **118***b* disposed adjacent the upper base **120***a* on a front face **124** of the fluke **110**. A central axis A-A extends through the entry end **112**, the trailing end **114**, the arm **122**, and the bases **120***a*, **120***b*.

A first plurality of elongated, T-shaped protrusions **125***a* extend normal from the upper base **120***a* away from the front face **124**, and a second plurality of elongated, T-shaped protrusions **125***b* extend normal from the upper base **120***a* away from a rear face. Pairs of elongated, T-shaped protrusions **125***a*, **125***b* that extend outwardly from each of the front face **124** and the rear face of the upper base **120***a* are aligned with each other to form an I-shaped cross-section as viewed from the trailing end **114** of the anchor **100**. Furthermore, distal ends **130** of each elongated, T-shaped protrusion **125***a*, **125***b* adjacent an outer perimeter **132** of the upper base **120***a* taper downwardly from the axis A-A to each side **134**, **136** of the fluke **110** to follow the triangular perimeter of the upper base **120***a*. The distal ends **130** of the T-shaped protrusions **125***a*, **125***b* and a lower edge **138** of the lower base **120***b* define a diamond shape as viewed from the front **124** or rear face.

In the implementation shown in FIGS. **11-13**, each hinge boss **118***a*, **118***b* is coupled to a distal face **135** of one of two T-shaped protrusions **125***a*. However, in other implementations (not shown), the hinges **118***a*, **118***b* may be coupled to the front face **124** of the upper base **120***a*.

The lower base **120** *b* is triangular shaped as viewed from the front face **124** or rear face of the fluke **110**. A first edge of the triangle is adjacent the upper base **120** *a*, and second and third edges extend from the first edge to form an apex along a leading surface (facing the entry end **112**) of the lower base **120** *b*. In addition, the front **124** and rear faces of the lower base **120** *b* taper toward each other along the second and third edges to form a hydrodynamic profile along the leading edge of the lower base **120** *b*. The front faces of the upper and lower bases **120** *a* and **120** *b* are the components that provide the bearing area to generate the holding capacity of the anchor **100**. The lift force generated by the flow of the water on upper and lower bases **120** *a* and **120** *b* while the anchor is free falling is applied approximately at the center of lift **302**, which is adjacent the junction between both bases, **120** *a* and **120** *b*. To provide hydrodynamic stability, the center of mass **301** has to be below this junction and the center of drag **303**. To achieve this arrangement, the lower base **120** *b* may be a bulkier piece of steel than the upper base **120** *a*, the upper base **120** *a* may be a structurally optimized thin plate of steel, reinforced with the T-shaped protrusions **125** *a*, **125** *b*, for example, and the arm **122** extends downwardly between the lower base **120** *b* and the entry end **112** to add weight in the lower portion of the anchor **100**. Also, the arm extends downwardly to provide additional eccentricity of the force applied by the anchor line **11** with respect to the center of the bearing area of the anchor

100 while the anchor **100** is rotating after embedding in the soil and prior to the triggering, or disengagement, of the coupling mechanism.

The various components of the fluke **110** may be formed of steel, for example. However, other materials may be used that are suitable for the application of the anchor **100**, such as materials that have sufficient strength to prevent cracking or breaking after installation in the soil below the water. For example, the fluke **110** may comprise a combination of steel in the lower base **120** *b* and in the T-shaped protrusions **125** *a*, **125** *b* and a lightweight material, such as carbon fiber, in the upper base **120** *a*. Building the upper base **120** *a* and the upper part of the T-shaped protrusions **125** *a*, **125** *b*, which are components above the center of lift **302**, with low weight, high strength materials as resins, carbon fiber, fiberglass, or similar provide a lower center of mass, reduce the size of the lower base **120** *b* and the arm **122**, reduce the overall weight of the anchor **100**, and may allow for a more efficient design.

In addition, the hinge bosses **118***a*, **118***b*, T-shaped protrusions **125***a*, **125***b*, lower base **120***b*, upper base **120***a*, and arm **122** may be integrally molded together. However, in other implementations, one or more of these features may be separately formed from the other features and coupled to the fluke **110** using suitable fastening mechanisms (e.g., welding or mechanical fasteners, such as bolts, screws, etc.).

The shank **150** includes an upper portion **155** and a lower portion **158** that are coupled together via a central portion **159**. The upper portion **155**, lower portion **158**, and central portion **159** are aligned along an axis B-B. The upper portion **155** includes two arms **156***a*, **156***b* that extend away in the axial direction from the central portion **159**. Distal ends of each arm **156***a*, **156***b* define at least one opening through which a pin (or other suitable fastener) may be engaged to secure the arms **156***a*, **156***b* to the hinge bosses **118***a*, **118***b*, respectively, such that the arms **156***a*, **156***b* may rotate about the pins. In the implementation shown in FIGS. **11-13**, the openings in the distal ends of each arm **156***a*, **156***b* align with openings defined in the hinge bosses **118***a*, **118***b*, and a pin **162***a*, **162***b* engages the respective openings to rotatably couple the arms **156***a*, **156***b* to the hinge bosses **118***a*, **118***b*. A washer **163***a*, **163***b* (or other planar bearing structure) may be disposed between the openings of the arms **156***a*, **156***b* and the openings of the hinges **118***a*, **118***b* to support the rotational movement of the arms **156***a*, **156***b* relative to the hinge bosses **118***a*, **118***b* when the shank **150** is moving toward its open position.

In addition, in the implementation shown in FIGS. **11-13**, each distal end of each arm **156***a*, **156***b* includes two spaced apart arms **164***a*, **164***b*, **164***c*, **164***d* that define the openings that are coupled to the hinge bosses **118***a*, **118***b*. Each set of spaced apart arms **164***a*, **164***b* and **164***c*, **164***d* is spaced apart a length that is at least as wide as the hinge boss **118***a*, **118***b*, respectively, to which the pair is coupled. However, in other implementations, each distal end of each arm **156***a*, **156***b* may define the openings without having the additional pairs of spaced arms **164***a*, **164***b*, **164***c*, **164***d*.

FIG. **17** illustrates a close up view of the coupling mechanism that allows anchor **100**, after pitching into the soil, to drastically change the eccentricity of the force being applied by the anchor line **11** to the fluke **110** by allowing the shank **150** to disengage from the fluke **110** at a predetermined angle. At first, the large eccentricity of the aforementioned force causes the anchor **100** to rotate within the soil. Then, after the shank **150** is liberated, the eccentricity changes direction and reduces its magnitude drastically, causing the anchor **100** to dive deeper into the soil.

Anchor **100** includes a protrusion **140** that extends away from the arm **122** of the fluke **110** in a direction extending outwardly from the front face **124**, of the fluke **110**. In particular, as viewed from the left side **134** of the fluke **110**, the protrusion **140** extends outwardly from the arm **122** in a plane that is perpendicular to the front face **124**. The protrusion **140** includes a hook shaped distal end that defines an inner arcuate shaped bearing surface **142** that faces towards the entry end **112** of the fluke **110**. An axis C-C extends through the geometric center of the arcuate shaped bearing surface **142** and is perpendicular to axis B-B that extends through each end of the shank **150**.

The entry end **112**, of the fluke **110**, is tapered to a point, as viewed from the side **134**, **136** of the fluke **110**, to create less drag as the anchor **100** drops through the water and less friction as it penetrates the soil. The protrusion **140** may be integrally molded with the arm **122** or separately formed and attached thereto using suitable fastening mechanisms.

The lower portion **158** of shank **150** includes two arms **166***a*, **166***b* that extend away from the central portion **159**. As shown in FIGS. **17** and **18**, each distal end of each arm **166***a*, **166***b* defines an elongated slot **168***a*, **168***b*, respectively, that has a length and width. The length is measured in the direction of the axis B-B, and the width is measured in a direction normal to axis B-B and axis C-C. The length of each slot **168***a*, **168***b* is larger than the width, and the slots **168***a*, **168***b* are aligned horizontally.

The anchor line **11**, which ends at link **192**, is attached to shank **150** by a coupling mechanism **185**, which can be seen by itself in FIG. **18**, and in a partial cut view in FIG. **19**. The coupling mechanism **185** includes a U-shaped hook **190**, a pin **180**, and a spool **182**. Spool **182** has a greater diameter than the pin **180**, is collinear to pin **180**, and is installed around it. Spool **182** freely rotates around pin **180** via roller bearings **184** disposed between an outer surface of pin **180** and an inner surface of spool **182**.

Pin **180** extends through the slots **168***a*, **168***b*. The diameter of the pin **180** is less than the width of the slots **168***a*, **168***b* to allow the pin **180** to rotate and move along axis B-B within the slots **168***a*, **168***b*. In addition, the shank coupling mechanism **185** includes annular rims **188** adjacent each side of the spool **182** that have a diameter greater than the central portion of the spool **182**. The central portion of the spool **182** extends between the annular rims **188**. The annular rims **188** keep spool **182** centered relative to the protrusion **140**.

Distal ends of a U-shaped hook **190** are fixed to the pin **180** adjacent outer (or distal) sides of the rims **188**, and a link **192** is coupled adjacent a central portion of the hook **190**. The link **192** is free to move independently of the hook **190**, but movement of the hook **190** moves the pin **180** since they are fixedly coupled together. In alternative implementations, the spool **182** may not include annular rims **188**.

FIG. **20**A presents a lateral view of arm **122**, entry end **112** and protrusion **140**, showing, as an example, the threshold angle of about 30 degrees between the normal to axis A-A and the force being applied by the anchor line **11** at which the shank coupling mechanism **185** would be triggered, as the bearing surface **142** ends at that threshold angle.

FIG. **20**B shows the lateral view of FIG. **20**A including a cut view of the coupling mechanism **185** at the point where the force has reached the threshold angle and further rotation of the anchor **100** is not possible. FIG. **20**C shows the same elements as FIG. **20**B when the angle between the force being applied by the anchor line **11** and the anchor **100** has gone beyond the threshold value, and the coupling mechanism **185** is disengaging the bearing surface **142**.

For installation of the anchor **100** into the soil below the water, the anchor line **11** is attached to the link **192**, and the spool **182** is engaged against the bearing surface **142** of protrusion **140**. In this closed position, which is shown in FIGS. **11** and **14**, the shank **150** is close to or substantially parallel with a central plane of the fluke **110** that contains axis A-A and extends through the arm **122**, the bases **120***a*, **120***b*, and each side **134**, **136** of the fluke **110**. The anchor **100** is dropped into the water with the entry end **112** facing the soil. After dropping the anchor **100**, it gets minimal or no resistance from anchor line **11**, which is reeled out, to allow the anchor **100** to gain speed. Slight resistance of the reeling process in vessel **10***a* and drag on the anchor line **11** urge the spool **182** to engage against the bearing surface **142**.

The anchor **100** enters the soil under its own weight and momentum from falling through the water. Frictional resistance from the soil slows the vertical movement of the anchor **100** to the point of stopping it. Anchor **100** remains static, embedded into the soil, in the same vertical position as while free falling thru the water. Installation vessel **10***a* transfers anchor line **11** to the vessel **10***b* to be moored. Environmental and operational loads acting on the moored vessel **10***b* are transferred to the anchor line **11**, which transfers the force first to the soil via friction and then to the anchor **100**. When the force being transmitted to anchor **100** reaches a threshold value, dependent on the soil characteristics and the anchor geometry, anchor **100** begins to pitch, as can be seen in FIG. **6**.

As the load on anchor line **11** increases, the pitch increases and the angle between a horizontal plane and a plane containing anchor **100** decreases. Also, as the load on anchor line **11** increases, the angle between a horizontal plane and the force applied to anchor **100** decreases, starting at close to about 90 degrees and never quite getting to 0 degrees. At a predetermined threshold angle between the force applied to the anchor **100** and axis A-A, which in FIG. **20**A, as an example, is about 60 degrees, the coupling mechanism **185** is triggered and the spool **182** rotates away from bearing surface **142** as can be inferred from FIG. **20**C. When the spool **182** rotates away from bearing surface **142**, pin **180** travels along elongated slots **168***a*, **168***b*.

When the spool **182** has cleared protrusion **140** and pin **180** is disposed at the distal ends of the slots **168***a*, **168***b*, the load applied by anchor line **11** no longer gets transmitted to the fluke **110** through the arm **122**. The anchor **100** as a whole stops pitching, and the shank **150** starts rotating about hinges **118***a*, **118***b*, as shown in FIGS. **7** and **8**, until the axis B-B of the shank **150** is collinear with the force being applied by anchor line **11** at the upper end **155** as shown in FIG. **9**. Having the force collinear with the axis B-B of the shank **150** makes the shank **150** stop turning and transfers the load to the fluke **110** through hinges **118***a*, **118***b*. At this point the eccentricity of the load applied to the fluke **110** has changed direction and diminished considerably, which makes the fluke **110** dive deeper into the soil as depicted in FIG. **9**. As the anchor **100** is diving deeper into the soil, the anchor line **11** is traversing more, which causes the shank **150** to rotate further away from the fluke **110** and ultimately reach its final position where the force applied by the anchor line **11** and the axis B-B of shank **150** are almost perpendicular to the fluke **110** and the maximum holding capacity of the anchor is attained. This configuration is shown in FIGS. **10**, **12**, and **15**.

FIGS. **14-16** illustrate an anchor **200** according to an alternative implementation. The structure of the fluke **210**, the hinge **218** disposed on the fluke **210**, and the upper portion **255** of the shank **250** are different from those described above in relation to anchor **100**, but the other features are similar to that of anchor **100**. In addition, the overall behavior during installation and operation, as well as the performance of the anchors **100**, **200** are similar.

The fluke **210** of anchor **200** includes two wings **222**, **224** that are coupled to a central frame **226** of the fluke **210**. The wings **222**, **224** have a rectangular shaped cross-section as viewed from a front face **220** of the fluke **210**. Wing **224** is disposed adjacent entry end **212** and has an airfoil shaped cross-section as viewed from the sides **234**, **236** of the fluke **210**. Wing **224** is oriented such that the leading edge of wing **224** faces toward the entry end **212** of the fluke **210**, and the trailing edge of the wing **224** faces toward the trailing end **214**. Wing **224** is thicker than wing **222** in order to bring the center of mass of the anchor **200** towards the entry end **212**.

Wing **222** is composed of sides **228** and **229**, each acting as a cantilever when deployed in the soil. Components **228** and **229** have a hexagonal cross section as viewed from the sides **234** and **236** of the fluke **210**. For structural reasons, the aforementioned cross section has a maximal thickness adjacent to frame **226** which tapers away from frame **226** in order to optimize the weight and make the portion of anchor **200** which is above the center of lift as light as possible. Wing **222** is disposed adjacent the trailing end **214** of the fluke **210**.

The frame **226** has a central portion **240** that extends between the leading edge of wing **222** and the trailing edge of wing **224**. The central portion **240** includes a hinge **218** that extends outwardly from the central portion **240** in a direction away from the front face **220** of the fluke **210**. The hinge **218** defines an opening extending horizontally through it.

Axis A'-A' extends between the entry end **212** and the trailing end **214**. The leading and trailing edges and faces of wings **222**, **224**, respectively, are substantially parallel. The central portion **240** of the frame **226** extends normally from the axis A'-A' away from the front **220** and rear faces of the fluke **210**, forming a truss that provides structural support to frame **226** to prevent it from flexing, overstress, or failure.

An upper portion **255** of shank **250** includes two arms **256***a*, **256***b* that each define an opening adjacent a distal end of each arm **256***a*, **256***b*. The opening of the hinge **218** and the openings of the arms **256***a*, **256***b* are aligned, and a pin **252** or other suitable fastener is engaged through the openings to rotatably couple the arms **256***a*, **256***b* to the hinge **218**. The shank **250** may rotate about the axis extending through the pin **252**.

However, in other implementations, the fluke may include any suitably shaped anchor (e.g., any planar geometry, such as triangular, square, round, etc.) that provides a center of mass below the center of lift and center of drag while the anchor is falling through the water. In addition, other suitable coupling mechanisms may be used that allow for the change in eccentricity that causes the anchor to rotate in the soil until the coupling mechanism disengages from the fluke and allows the anchor to dive deeper into the soil. The diving behavior of the anchor depends, at least in part, on the surface area of the front face of the fluke and the distance from the front face of the fluke to the point at which the shank attaches to the hinges. Thus, the surface area and/or the distance between the front face of the fluke and the hinge attachment point may vary so long as the combination of anchor features allows for the aforementioned diving behavior.

Furthermore, although the flukes **110**, **210** described above have a specific shape, other hydro-dynamically shaped flukes may be used in accordance with various implementations of the invention. In particular, flukes that provide a center of mass below the center of lift and the center of drag allows the anchor to drop straight down in the water or restore itself to vertical if perturbed. This feature allows the anchor to be installed without additional or sacrificial weight and without the use of additional equipment or vessels. The weight of the anchor is sufficient to contribute to the free-fall penetration through the water and soil. Furthermore, alternative coupling mechanisms, such as a pendulum, magnet, or an electronic switch, may be used to engage the lower end of the shank adjacent the entry end of the fluke for free fall through the water and initially into the soil and disengage the lower end of the shank when the load causes the angle of the line relative to the fluke to reach a certain threshold angle (e.g., about 60 degrees).

In some implementations, an electromagnetic source is attached to the anchor, and the field generated by the source is used to track the location, depth, and orientation of the anchor during installation and service. Such implementations may be useful when the anchor is used to secure permanent or semi-permanent facilities, for example.

When it is loaded in service, the anchor pitches, dives deeper and ultimately provides the maximum possible holding capacity with the line pulling normal to the front face of the fluke of the anchor. This innovation of progressing from a vertical orientation to one with the line pulling close to or substantially normal to the fluke is achieved with a triggered hinge that holds the shank substantially parallel to the fluke until the angle between the line and the fluke exceeds the threshold angle.

Various modifications of the devices and methods in addition to those shown and described herein are intended to fall within the scope of the appended claims. Further, while only certain representative devices and method steps disclosed herein are specifically described, other combinations of the devices and method steps are intended to fall within the scope of the appended claims, even if not specifically recited. Thus, a combination of steps, elements, components, or constituents may be explicitly mentioned herein. However, other combinations of steps, elements, components, and constituents are included, even though not explicitly stated. The term "comprising" and variations thereof as used herein is used synonymously with the term "including" and variations thereof and are open, non-limiting terms.

The invention claimed is:

1. An anchor comprising:

a shank having first and second ends;

a fluke having an entry end, a trailing end, and a central portion intermediate the entry and trailing ends;

a bearing surface disposed adjacent the entry end of the fluke; and

a pin disposed adjacent the second end of the shank, the (1) engaging the bearing surface of the fluke during passage of the anchor through water and while embedding vertically into the soil, (2) transmitting a force applied by an anchor line to a front surface of the fluke causing the anchor to pitch, and (3) disengaging the bearing surface when a threshold angle between the force applied by the anchor line and the fluke is attained, causing the anchor to translate near parallel to the fluke,

wherein:

a first end of the shank is rotatably coupled adjacent a central area of the front surface of the fluke,

when the pin is engaged with the bearing surface, a center of mass of the anchor is below a center of drag and a center of lift of the anchor to keep the anchor vertically oriented such that the entry end of the fluke is vertically below and aligned with the trailing end of the fluke while passing through water, and

a weight of the anchor urges the anchor through the water and into soil below the water.

2. The anchor of claim **1**, wherein at least a portion of the fluke is diamond shaped.

3. The anchor of claim **2**, wherein the diamond shaped portion of the fluke is adjacent the trailing end.

4. The anchor of claim **3**, wherein the fluke comprises a planar base and T-shaped protrusions, the T-shaped protrusions extend from a front face and a rear face of the base as viewed from the trailing end of the fluke.

5. The anchor of claim **1**, wherein the trailing end of the fluke is triangular-shaped.

6. The anchor of claim **1**, wherein the fluke comprises a first wing adjacent the trailing end of the fluke and a second wing disposed between the trailing end and the entry end of the fluke, wherein the second wing has a rectangular cross sectional shape as viewed from a front or a rear surface of the fluke and an airfoil cross-sectional shape as viewed from a side surface of the fluke.

7. The anchor of claim **1**, wherein:

a protrusion extends outwardly from the front face of the fluke, wherein a proximal end of the protrusion is disposed adjacent the front face of the entry end of the fluke, and the bearing surface comprises a surface of the protrusion that faces the entry end of the fluke, and

the shank further comprises:

two arms spaced apart from each other disposed at the second end of the shank, each of the two arms defining an elongated slot there through, wherein the elongated slots are aligned with each other along a first axis that extends through each arm and is perpendicular to a second axis extending through each end of the shank, and the elongated slots have the same slot width and length, and

the pin is disposed between the two arms and extends through the elongated slots and is configured to move through the slots along the second axis,

wherein a central portion of the pin engages the bearing surface to hold the second axis of the shank adjacent a third axis extending through each end of the fluke when the pin is disposed at proximal ends of the elongated slots, and the central portion of the pin disengages the bearing surface when the pin is disposed at distal ends of the elongated slots, allowing the second axis of the shank to rotate about the second end of the shank relative to the third axis of the fluke.

8. The anchor of claim **7**, wherein the central portion of the pin comprises a spool extending radially outwardly from an axis extending through each end of the pin, the spool configured for rotating freely around the axis of the pin.

9. The anchor of claim **8**, further comprising a U-shaped hook, wherein ends of the U-shaped hook are coupled to the pin adjacent each end of the spool.

10. The anchor of claim **9**, further comprising a link coupled to the U-shaped hook, the link being configured for coupling to the anchor line.

11. The anchor of claim **7**, further comprising a U-shaped hook, wherein ends of the U-shaped hook are coupled to the pin adjacent a central portion of the pin.

12. The anchor of claim **11**, further comprising a link coupled to the U-shaped hook, the link being configured for coupling with a line, the line extending between the anchor and the vessel.

13. The anchor of claim **1**, wherein the first end of the shank comprises first and second arms that are spaced apart from each other and are each rotatably coupled to the central portion of the fluke.

14. The anchor of claim **1**, wherein the central portion of the pin comprises a spool extending radially outwardly from an axis extending through each end of the pin, the spool being freely rotatable around the axis of the pin, and the spool engaging the bearing surface of the fluke during passage of the anchor through the water and while embedding vertically into the soil and disengaging the bearing surface when the threshold angle between the force applied by the anchor line and the fluke is attained.

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